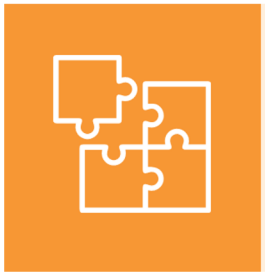
NCST Investigation of the Champlain Towers South Collapse

Investigation Update

Glenn R. Bell
Associate Lead Investigator

Agenda

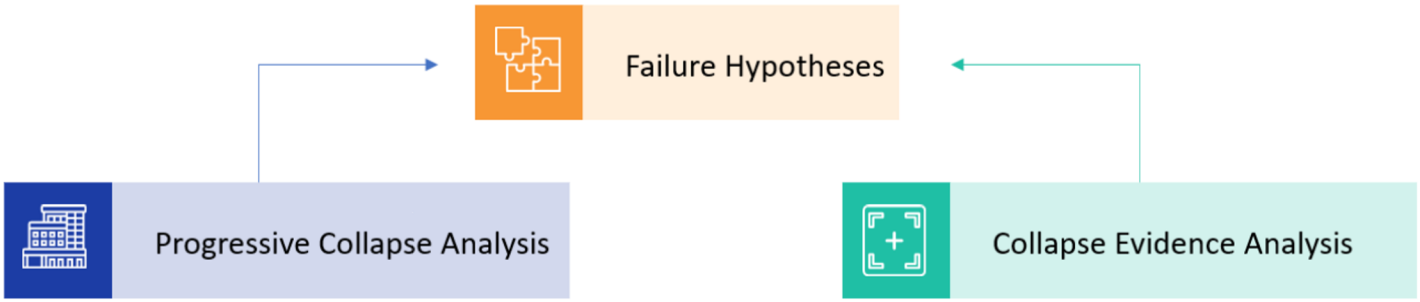
- Review investigative goals and approach
  - Failure hypotheses
  - Non-quantitative evidence
  - Collapse sequence
  - Uncertainty
- Investigation management
  - Team integration
  - Schedule, milestones, and interdependencies
  - Budget
- Invasive testing
- Development of recommendations



Failure Hypotheses

A *failure hypothesis* is an investigative supposition about where and how the failure occurred with likely contributing causes.

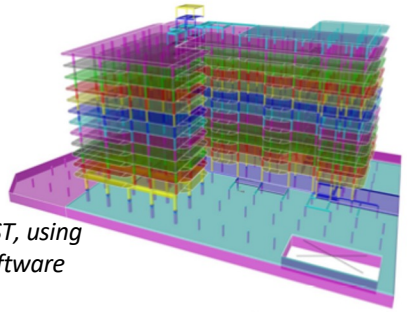
- Examination of failure hypotheses is a constant investigative activity
- Includes both initiation and progression of the failure
- Must find a single valid hypothesis and disprove the others
- Multiple potential causes and contributors
- Currently numerous active hypotheses
- We have ruled out nothing at this time


Failure Hypotheses
Progressive Collapse Analysis
Collapse Evidence Analysis

Failure Hypotheses

Progressive Collapse Analysis

Collapse Evidence Analysis



Source: NIST, using ETABS software

Laboratory tests
Computer simulation

Building Loads

Building Strength

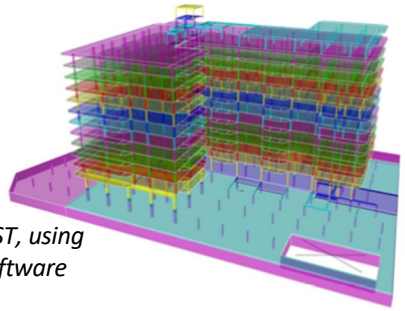
Source: NIST

not CTS

Source: except where noted, NIST

Failure Hypotheses

Progressive Collapse Analysis



Source: NIST, using ETABS software

Collapse Evidence Analysis

Source: NIST

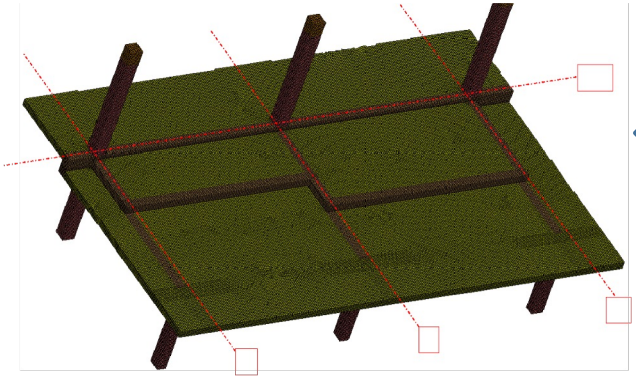
Laboratory tests
Computer simulation

Building Loads

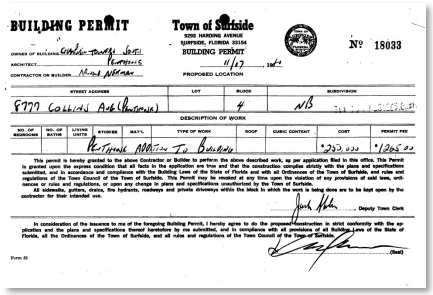
Building Strength

Source: NIST *not CTS*

Collapse Sequence



Source: NIST, using LS-DYNA software



Source: Town of Surfside, FL

Source: except where noted, NIST

timeline

Uncertainty

Activities to date

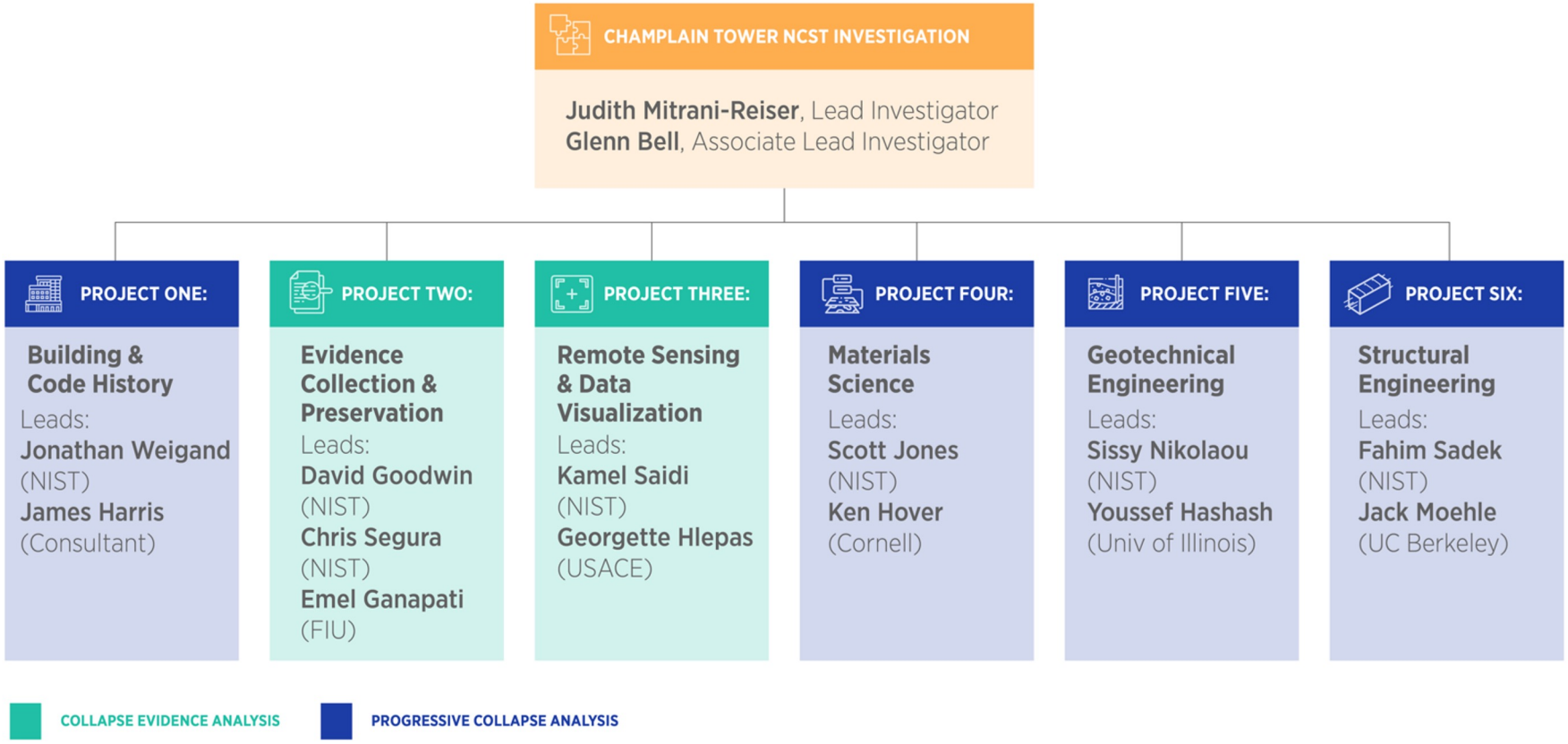
- Engaged team members with expertise in Uncertainty Quantification (UQ)
- Engaged potential contract consultants with expertise in UQ
- Engaged NIST's Statistical Engineering Division
- Conducted an extensive literature search
- Held a half-day investigation workshop on UQ in January
- Routinely consider uncertainty in our measurements
- Consider uncertainty and statistical needs in our sampling and testing plans

Challenge

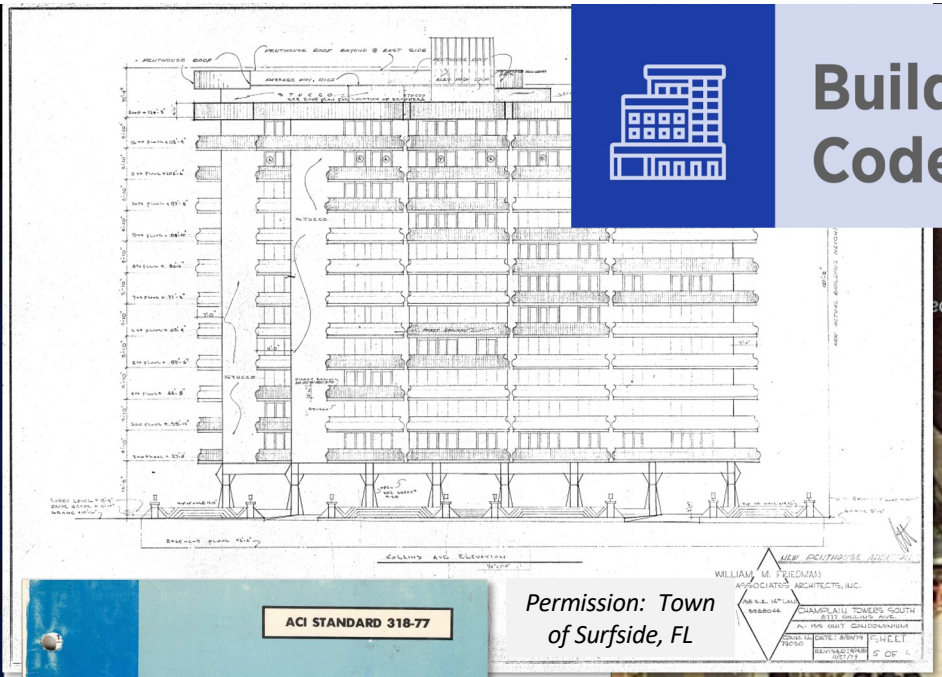
- How to rigorously consider UQ in our quantitative work using models that are simple enough to be manageable

The marriage of the quantitative **Progressive Collapse Analysis** and the non-quantitative **Collapse Evidence Analysis** will be the key to managing uncertainty in this investigation.

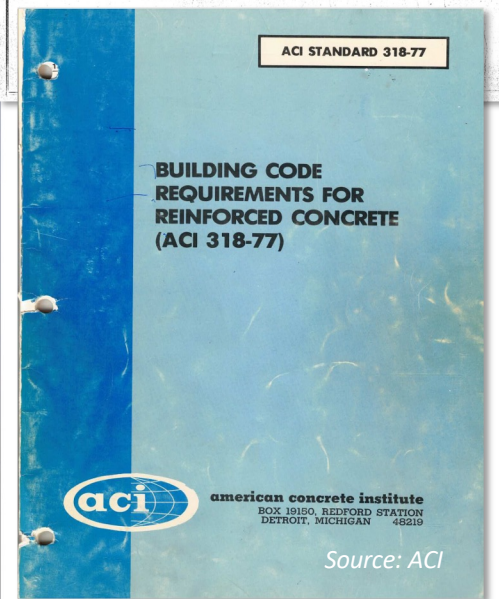
Champlain Towers South NCST Investigation Leaders



Building & Code History



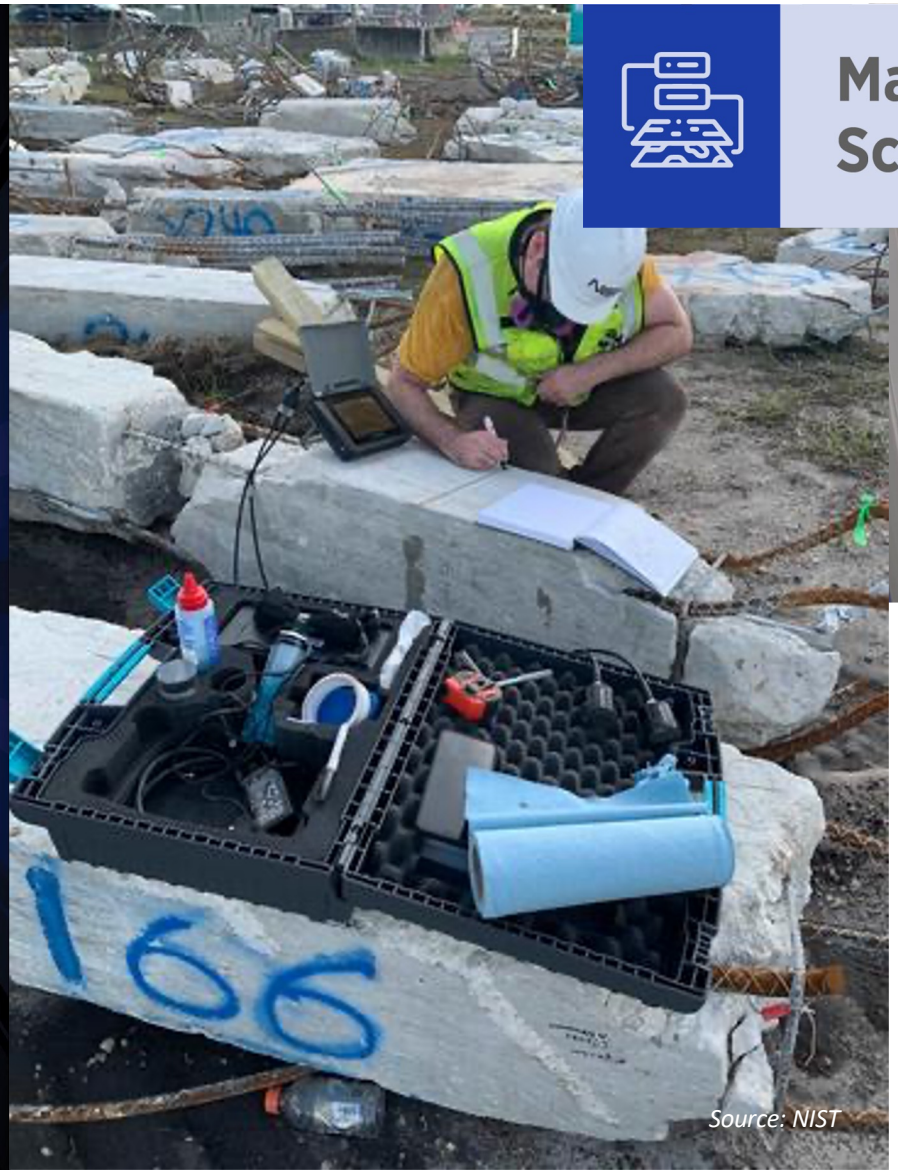
Permission: Town of Surfside, FL



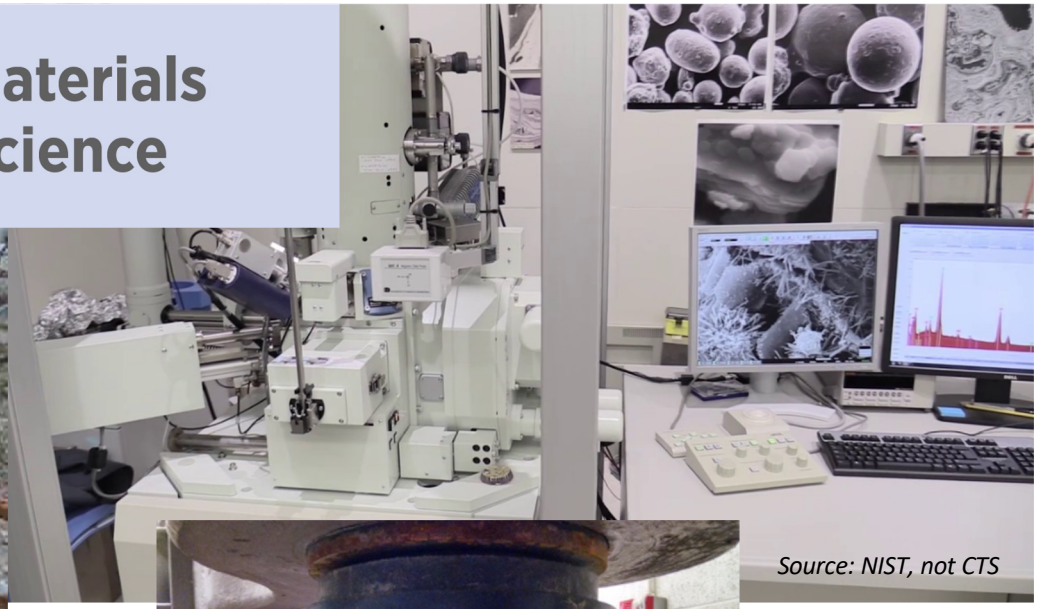
Source: ACI

Google Earth image captured 12/2017; downloaded 5/10/2022

Materials Science



Source: NIST


Source: NIST, not CTS


Source: NIST, not CTS

engineering laboratory

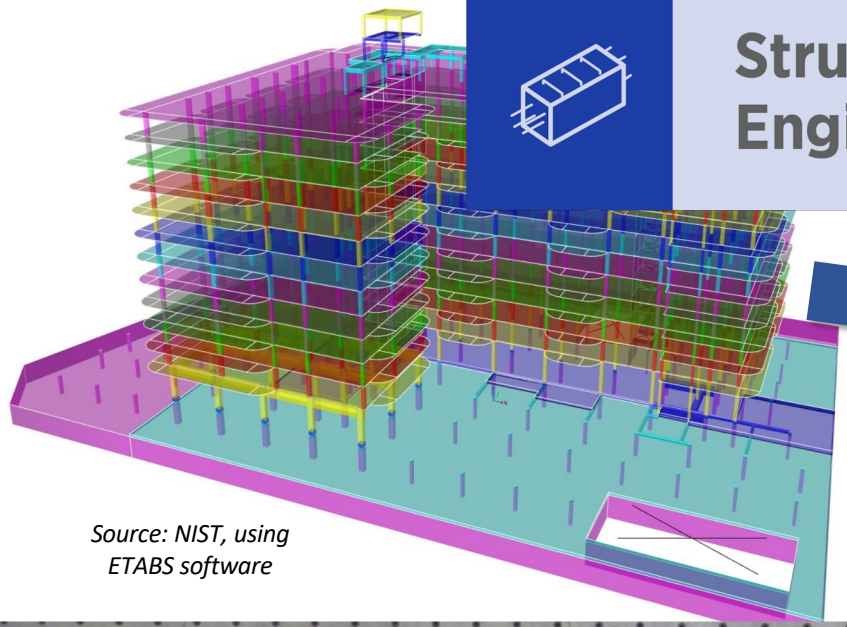
NCST Advisory Committee Meeting, June 8-9, 2022

Geotechnical Engineering

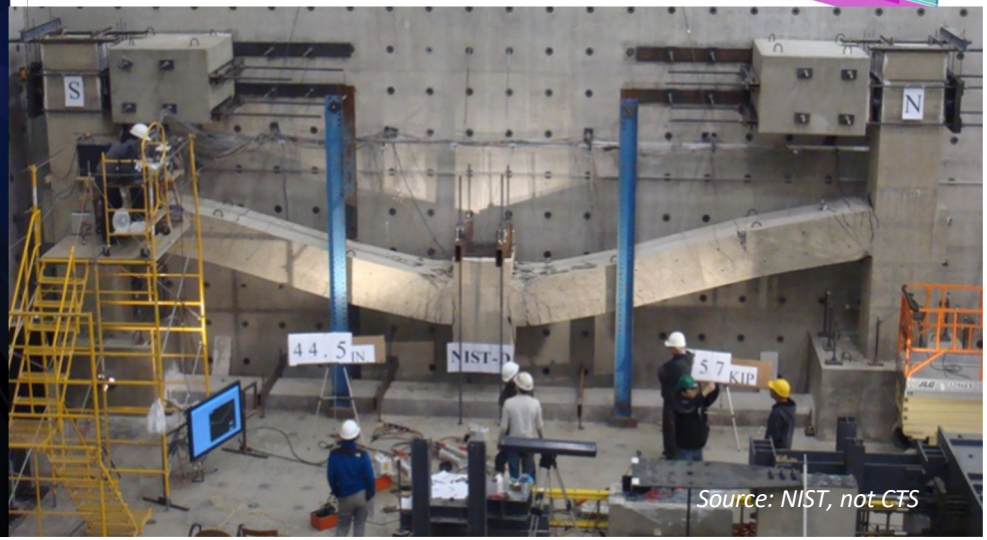
Source: NIST

Source: NIST

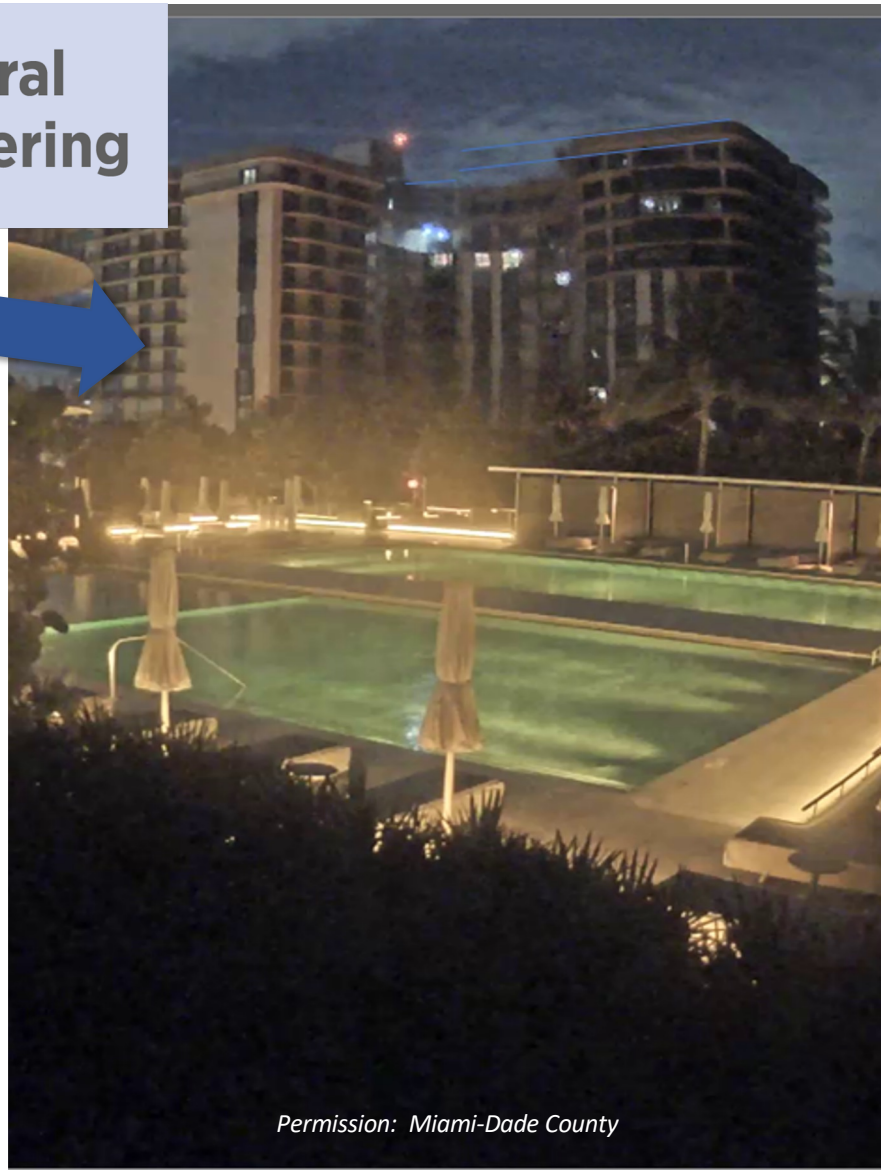
Structural Engineering



Source: NIST, using ETABS software

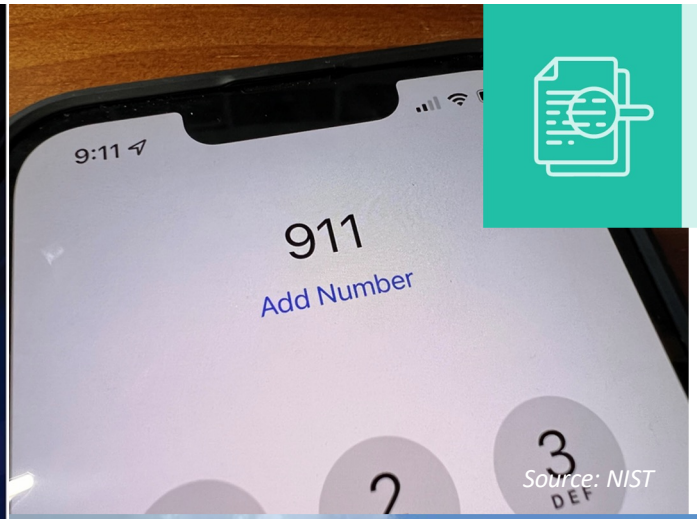


Source: NIST, not CTS



Permission: Miami-Dade County

Evidence Collection & Preservation

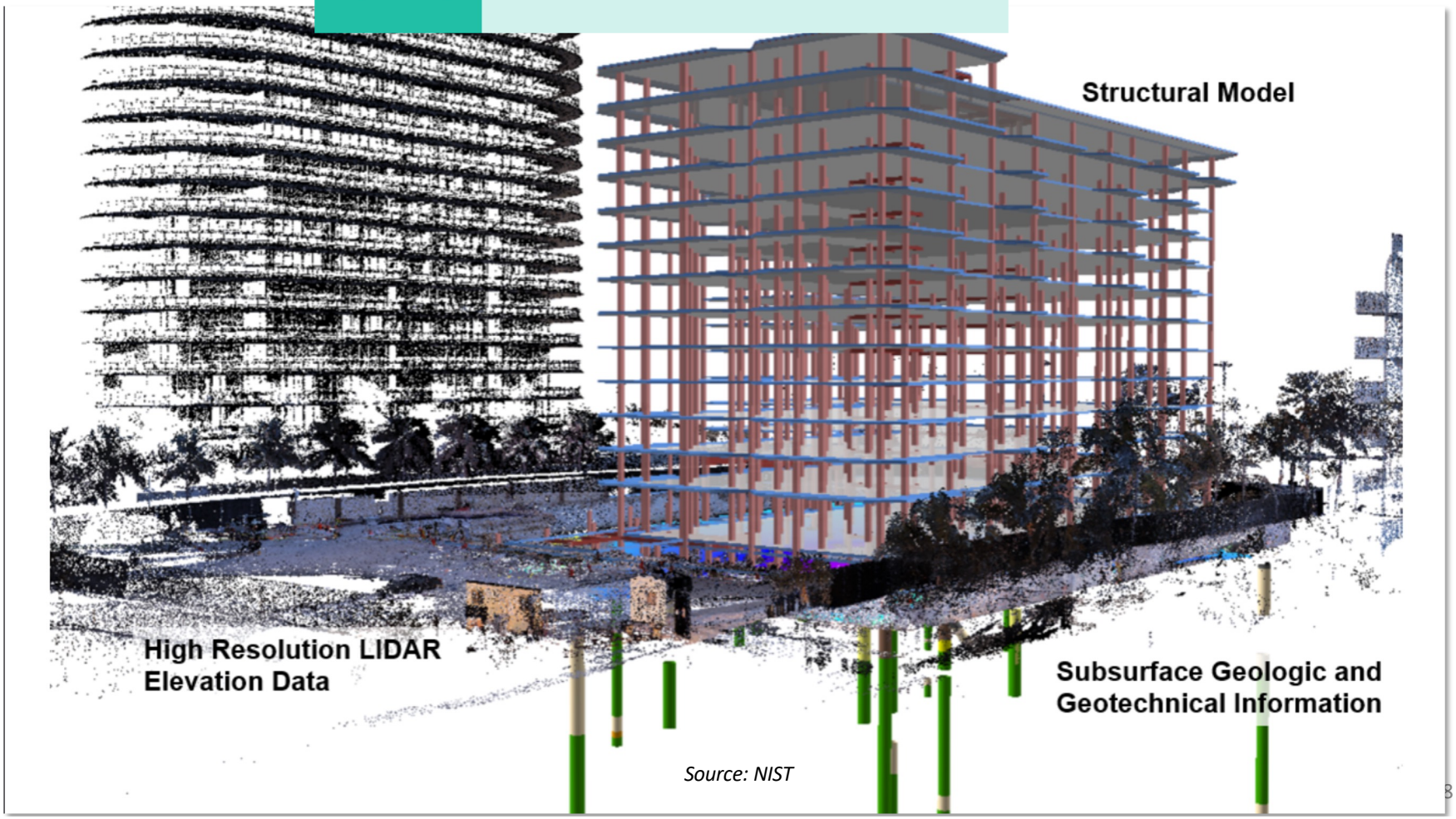


Source: NIST

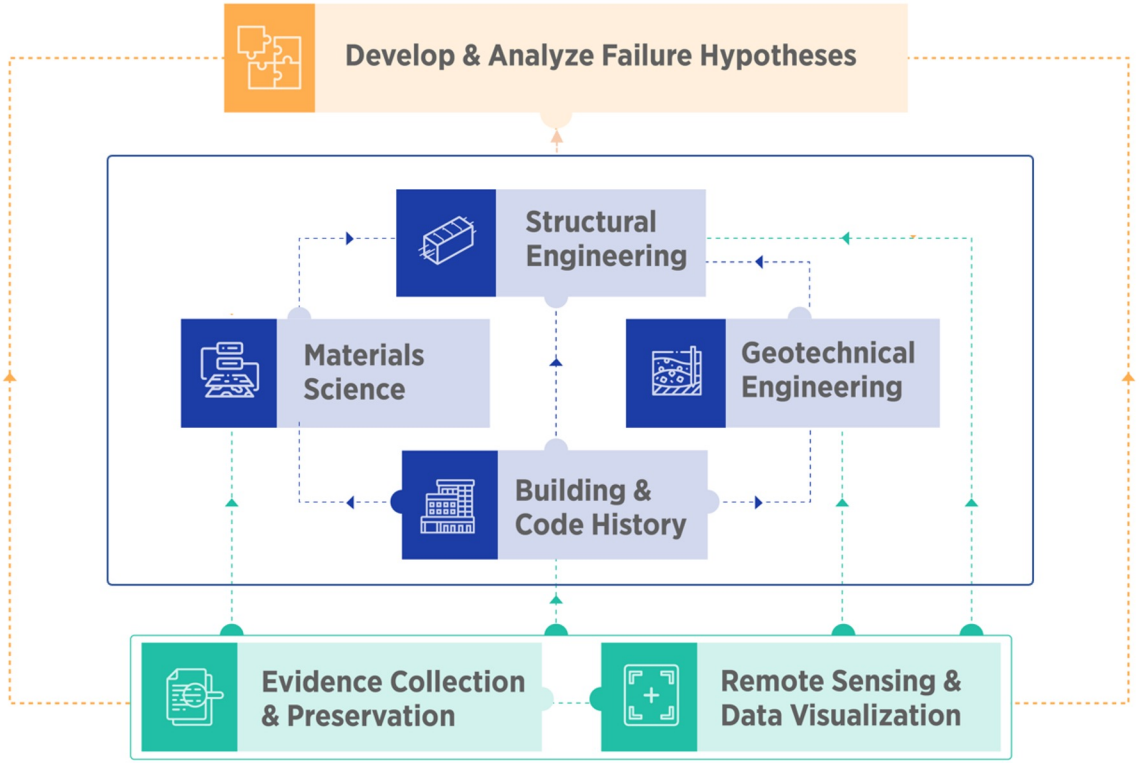
Source: NIST

Source: NIST

Remote Sensing & Data Visualization

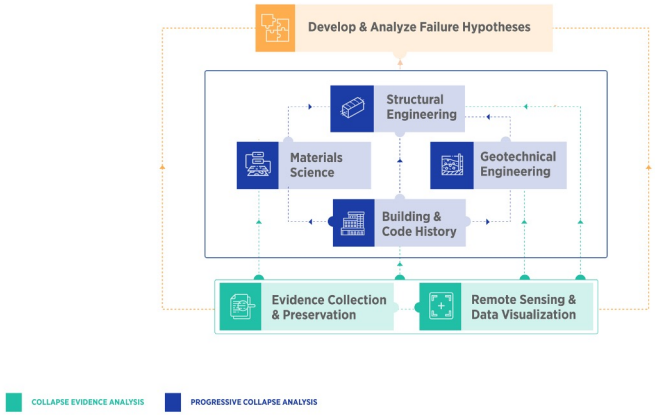


Source: NIST


Develop & Analyze Failure Hypotheses
Structural Engineering
Materials Science
Geotechnical Engineering
Building & Code History
Evidence Collection & Preservation
Remote Sensing & Data Visualization
COLLAPSE EVIDENCE ANALYSIS
PROGRESSIVE COLLAPSE ANALYSIS

Investigation Management – Team Integration

Continuous communication amongst teams



Periodic meetings

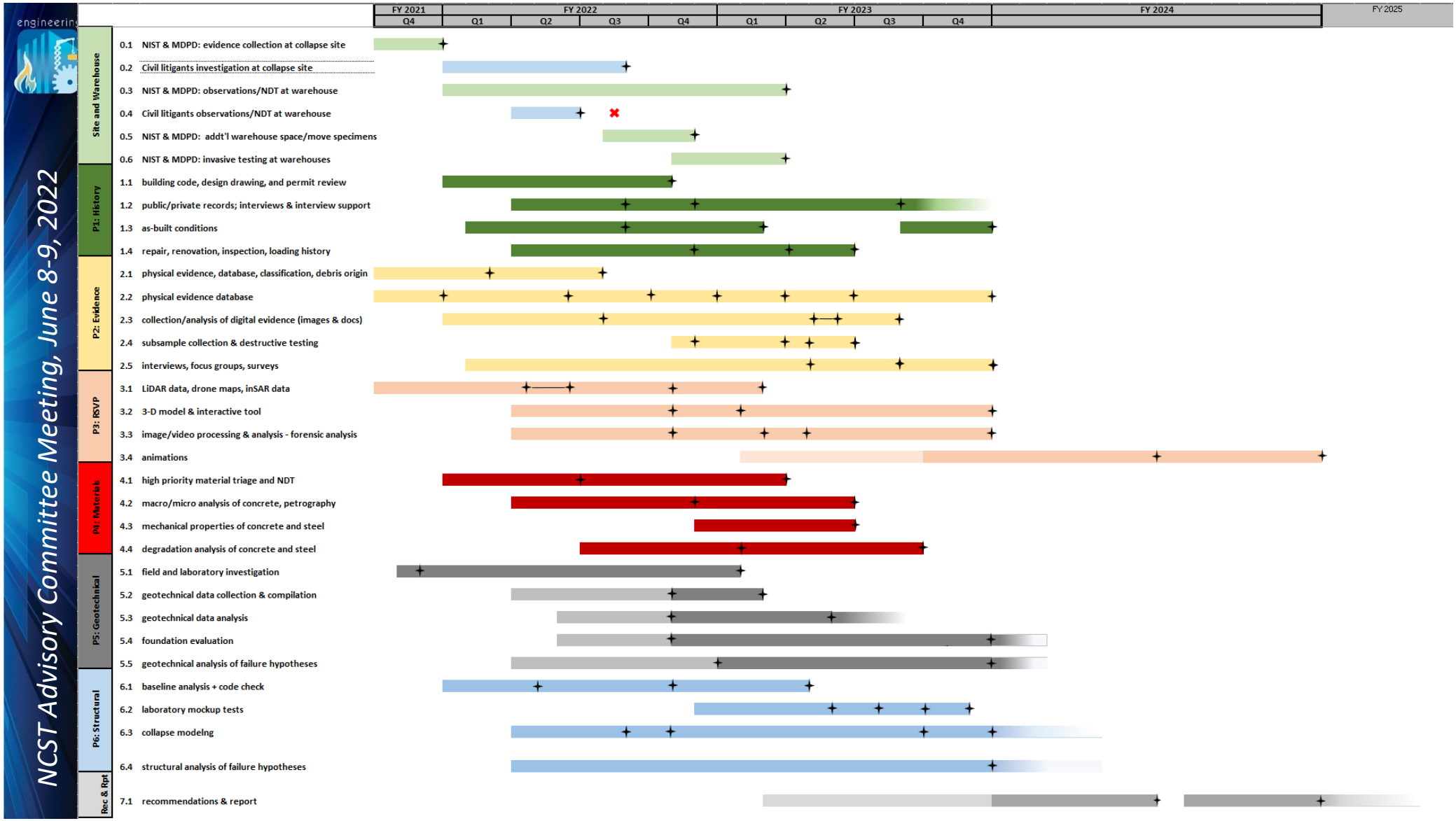
- Weekly investigation leadership meetings (Judy and Glenn)
- Periodic project team meetings
- Biweekly all-team-lead project management meetings
- Biweekly all-team-members meetings

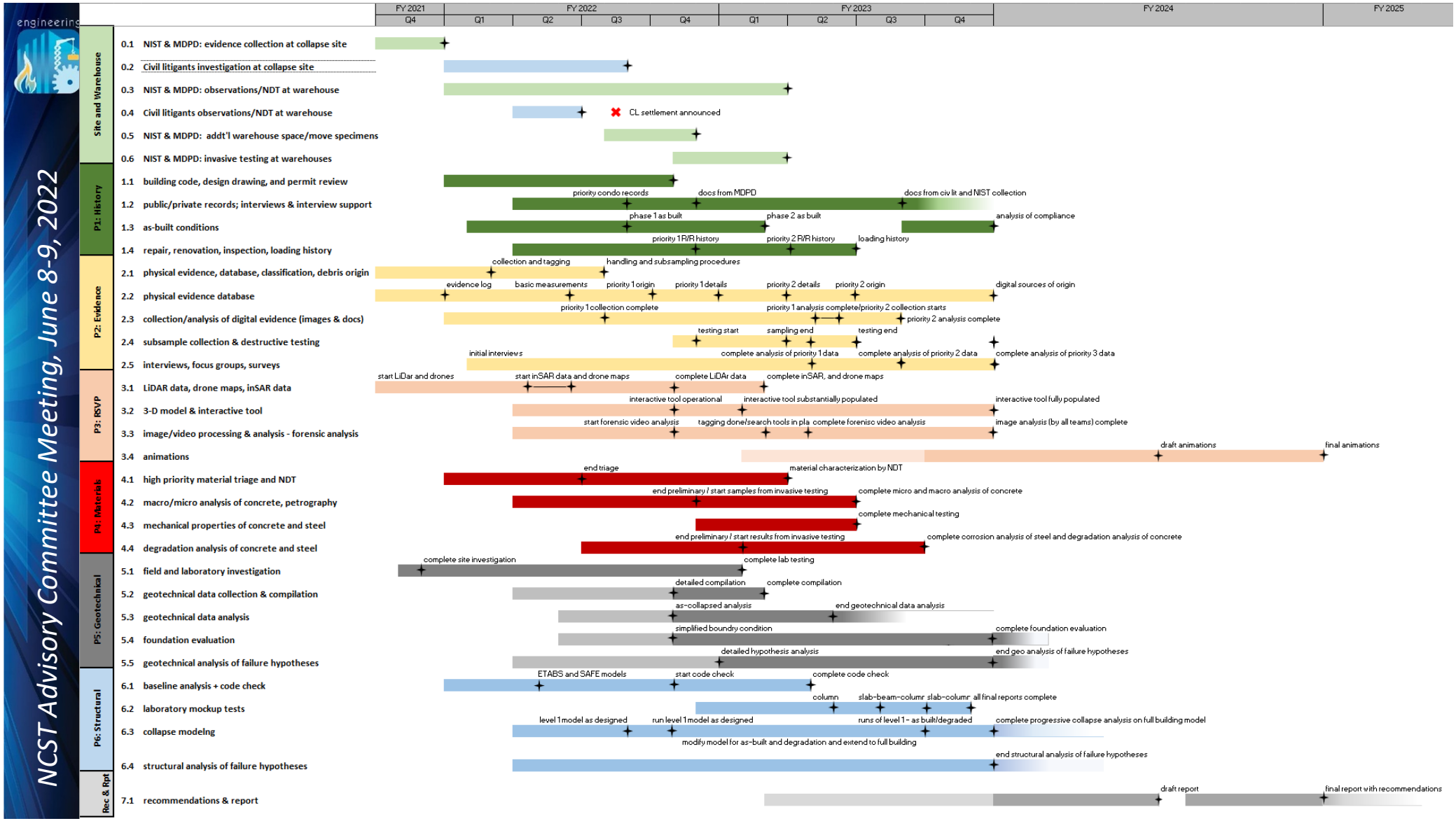
Shared databases

- Evidence database
- Shared internal drives
- 3-D geospatial model
- NIST library solutions

Whole-investigation tiger teams and initiatives

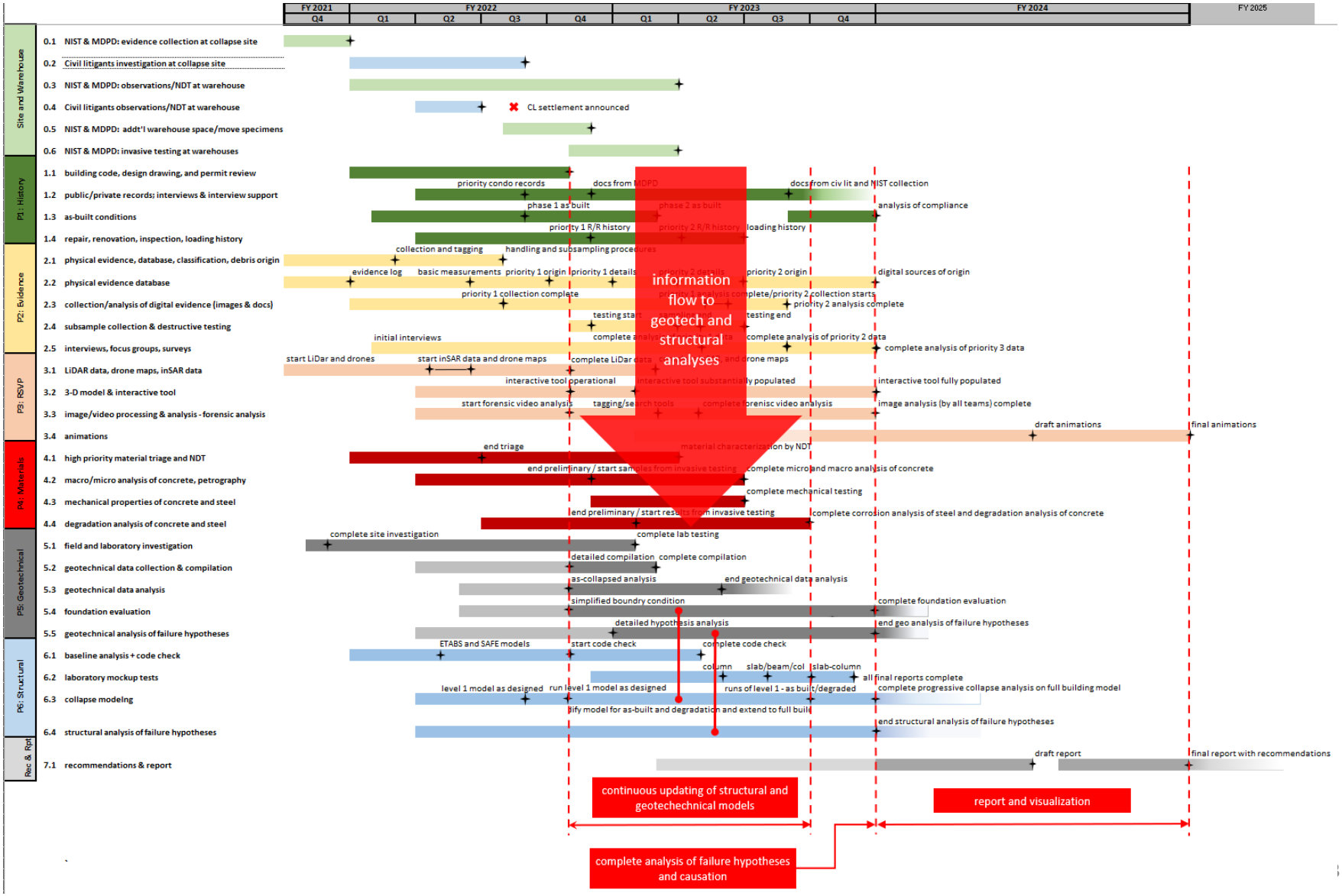
- Invasive testing
- Evidence
- Failure hypotheses
- Uncertainty quantification


engineering
NCST Advisory Committee Meeting, June 8-9, 2022
FY 2021
Q4
FY 2022
Q1
Q2
Q3
Q4
FY 2023
Q1
Q2
Q3
Q4
FY 2024
FY 2025
Site and Warehouse
P1: History
P2: Evidence
P3: RSVP
P4: Materials
P5: Geotechnical
P6: Structural
Rec & Rpt
0.1 NIST & MDPD: evidence collection at collapse site
0.2 Civil litigants investigation at collapse site
0.3 NIST & MDPD: observations/NDT at warehouse
0.4 Civil litigants observations/NDT at warehouse
0.5 NIST & MDPD: addt'l warehouse space/move specimens
0.6 NIST & MDPD: invasive testing at warehouses
1.1 building code, design drawing, and permit review
1.2 public/private records; interviews & interview support
1.3 as-built conditions
1.4 repair, renovation, inspection, loading history
2.1 physical evidence, database, classification, debris origin
2.2 physical evidence database
2.3 collection/analysis of digital evidence (images & docs)
2.4 subsample collection & destructive testing
2.5 interviews, focus groups, surveys
3.1 LiDAR data, drone maps, inSAR data
3.2 3-D model & interactive tool
3.3 image/video processing & analysis - forensic analysis
3.4 animations
4.1 high priority material triage and NDT
4.2 macro/micro analysis of concrete, petrography
4.3 mechanical properties of concrete and steel
4.4 degradation analysis of concrete and steel
5.1 field and laboratory investigation
5.2 geotechnical data collection & compilation
5.3 geotechnical data analysis
5.4 foundation evaluation
5.5 geotechnical analysis of failure hypotheses
6.1 baseline analysis + code check
6.2 laboratory mockup tests
6.3 collapse modelng
6.4 structural analysis of failure hypotheses
7.1 recommendations & report

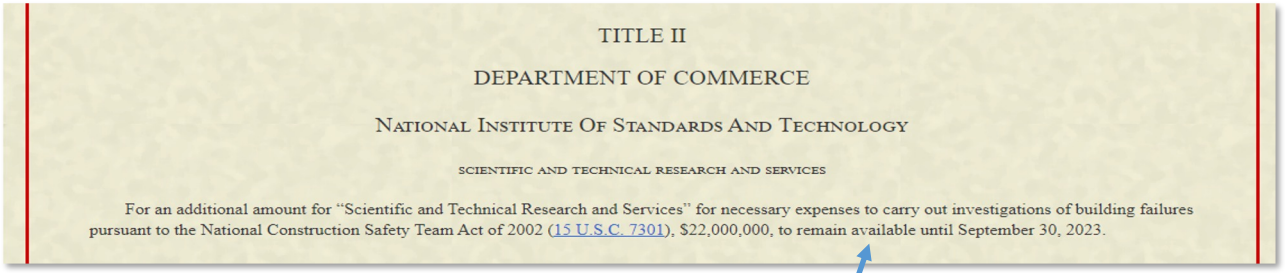

NCST Advisory Committee Meeting, June 8-9, 2022
engineering
FY 2021
FY 2022
FY 2023
FY 2024
FY 2025
Q4
Q1
Q2
Q3
Q4
Q1
Q2
Q3
Q4
Site and Warehouse
P1: History
P2: Evidence
P3: RSVP
P4: Materials
P5: Geotechnical
P6: Structural
Rec & Rpt
0.1 NIST & MDPD: evidence collection at collapse site
0.2 Civil litigants investigation at collapse site
0.3 NIST & MDPD: observations/NDT at warehouse
0.4 Civil litigants observations/NDT at warehouse
CL settlement announced
0.5 NIST & MDPD: addt'l warehouse space/move specimens
0.6 NIST & MDPD: invasive testing at warehouses
1.1 building code, design drawing, and permit review
1.2 public/private records; interviews & interview support
priority condo records
docs from MDPD
docs from civ lit and NIST collection
1.3 as-built conditions
phase 1 as built
phase 2 as built
analysis of compliance
1.4 repair, renovation, inspection, loading history
priority 1 R/R history
priority 2 R/R history
loading history
2.1 physical evidence, database, classification, debris origin
collection and tagging
handling and subsampling procedures
2.2 physical evidence database
evidence log
basic measurements
priority 1 origin
priority 1 details
priority 2 details
priority 2 origin
digital sources of origin
2.3 collection/analysis of digital evidence (images & docs)
priority 1 collection complete
priority 1 analysis complete/priority 2 collection starts
priority 2 analysis complete
2.4 subsample collection & destructive testing
testing start
sampling end
testing end
2.5 interviews, focus groups, surveys
initial interviews
complete analysis of priority 1 data
complete analysis of priority 2 data
complete analysis of priority 3 data
3.1 LiDAR data, drone maps, inSAR data
start LiDar and drones
start inSAR data and drone maps
complete LiDAr data
complete inSAR, and drone maps
3.2 3-D model & interactive tool
interactive tool operational
interactive tool substantially populated
interactive tool fully populated
3.3 image/video processing & analysis - forensic analysis
start forensic video analysis
tagging done/search tools in pla
complete forenisc video analysis
image analysis (by all teams) complete
3.4 animations
draft animations
final animations
4.1 high priority material triage and NDT
end triage
material characterization by NDT
4.2 macro/micro analysis of concrete, petrography
end preliminary / start samples from invasive testing
complete micro and macro analysis of concrete
4.3 mechanical properties of concrete and steel
complete mechanical testing
4.4 degradation analysis of concrete and steel
end preliminary / start results from invasive testing
complete corrosion analysis of steel and degradation analysis of concrete
5.1 field and laboratory investigation
complete site investigation
complete lab testing
5.2 geotechnical data collection & compilation
detailed compilation
complete compilation
5.3 geotechnical data analysis
as-collapsed analysis
end geotechnical data analysis
5.4 foundation evaluation
simplified boundry condition
complete foundation evaluation
5.5 geotechnical analysis of failure hypotheses
detailed hypothesis analysis
end geo analysis of failure hypotheses
6.1 baseline analysis + code check
ETABS and SAFE models
start code check
complete code check
6.2 laboratory mockup tests
column
slab-beam-columr
slab-columr
all final reports complete
6.3 collapse modelng
level 1 model as designed
run level 1 model as designed
runs of level 1 - as built/degraded
complete progressive collapse analysis on full building model
modify model for as-built and degradation and extend to full building
6.4 structural analysis of failure hypotheses
end structural analysis of failure hypotheses
7.1 recommendations & report
draft report
final report with recommendations

engineering laboratory

NCST Advisory Committee Meeting, June 8-9, 2022



Investigation Management – Budget



TITLE II

DEPARTMENT OF COMMERCE

NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY

SCIENTIFIC AND TECHNICAL RESEARCH AND SERVICES

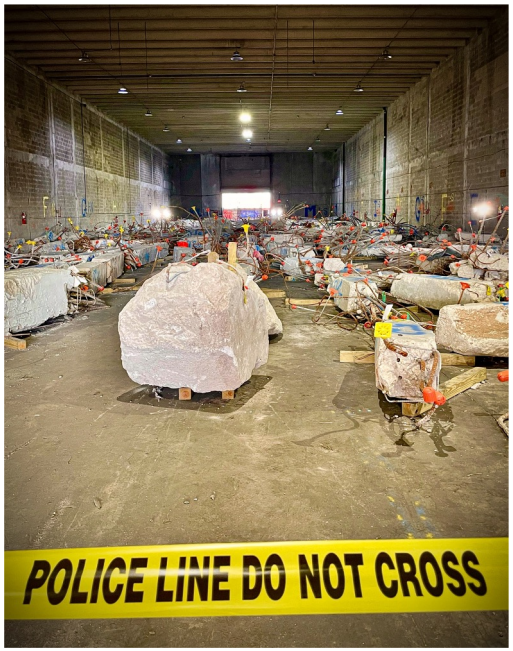
For an additional amount for "Scientific and Technical Research and Services" for necessary expenses to carry out investigations of building failures pursuant to the National Construction Safety Team Act of 2002 (15 U.S.C. 7301), $22,000,000, to remain available until September 30, 2023.

$22,000,000, to remain available until September 30, 2023

NIST's budget allocation of the $22 million

Item	Amount	Percent of $22M
Labor	$10M	45%
Contracts	$8.5M	39%
Equipment	$1.5M	7%
Travel and misc.	$2M	9%

Invasive Testing Plan



Source: NIST

over 600 pieces of physical evidence

Considerations

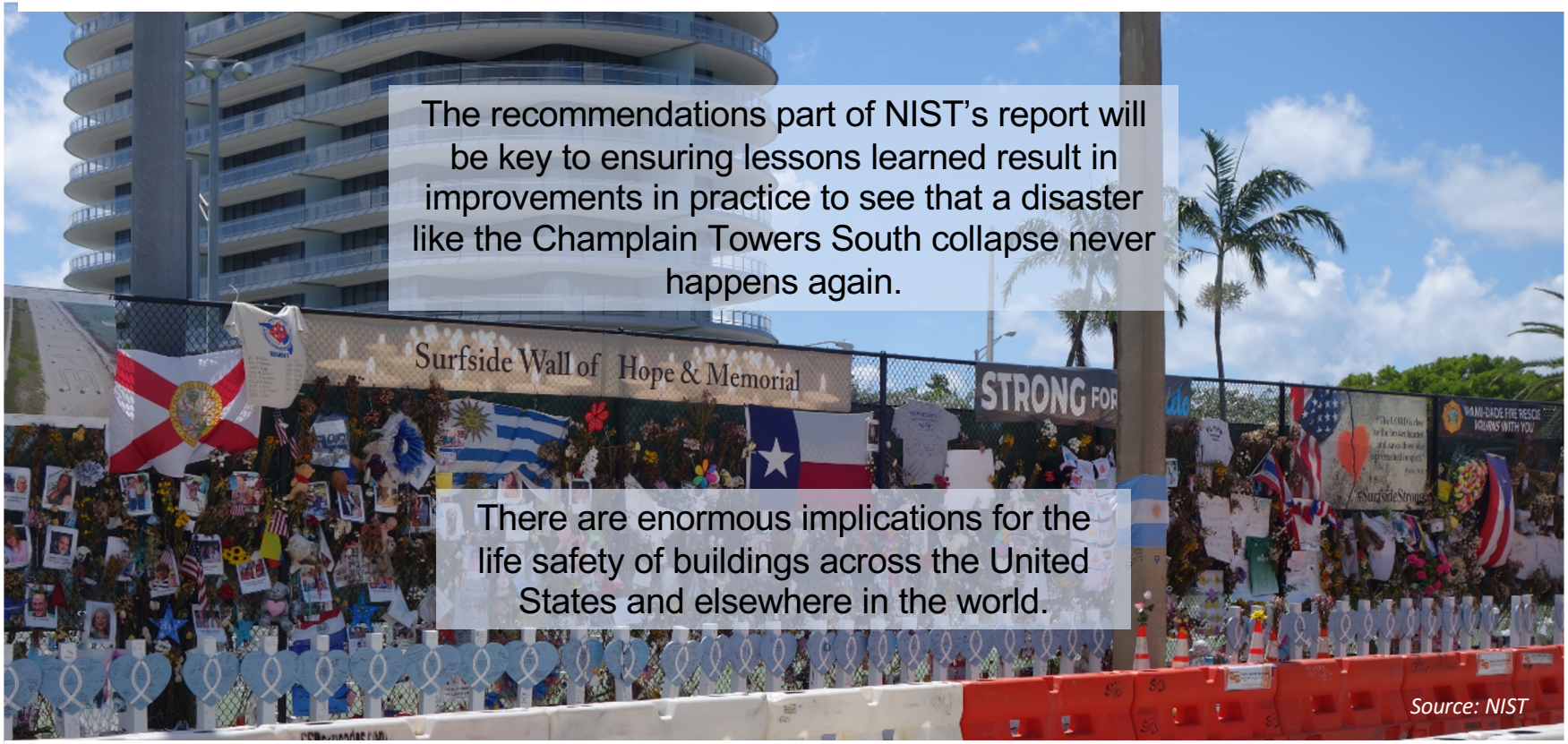
- Analysis of failure hypotheses
- Input for structural tests and computer modeling
- Input for material characterization and degradation mechanisms
- Evidence database > location in structure
- Non-destructive testing
- Sampling strategies for characterization (statistics/uncertainty)

Invasive testing plan

- Extract and test several hundred concrete samples
- Extract and test approximately 200 reinforcement samples

Structural/mechanical properties	• Material/chemical properties • Degradation mechanisms

Development of Recommendations



The recommendations part of NIST's report will be key to ensuring lessons learned result in improvements in practice to see that a disaster like the Champlain Towers South collapse never happens again.

There are enormous implications for the life safety of buildings across the United States and elsewhere in the world.

Source: NIST

NCST Investigation of the Champlain Towers South Collapse

Investigation Update

Presenters: Glenn Bell
Associate Lead Investigator
glenn.bell@nist.gov

Questions?

Please 'raise your hand' using the Blue Jeans Participant window and unmute your audio and video